# Lab Notebooks

Students are expected to keep a lab notebook for this course. All data, observations, comments, analysis, and conclusions should be written in the lab notebook. The lab notebooks should be turned in every week for grading (the due date is given in the syllabus) and will be handed back at the beginning of the next lab.

Lab notebooks are in common use in both science and engineering. Anyone who plans to have anything to do with research should be prepared to keep a lab notebook. Lab notebooks serve two purposes: (1) if well-organized, the lab notebook can serve as a reference, in which you (or someone else) could easily look up the results of a particular measurement *years* after the experiment was performed, and (2) if properly maintained, a lab notebook can serve as a *legal document* establishing a timeline for the development of research, and the validity of its results. Patents can be won or lost based on the existence and contents of an original lab notebook.

## Lab notebook requirements

The following are a list of requirements concerning the lab notebook you will keep for this course. Many of these requirements are necessary in order for the lab notebook to be considered a valid legal document. Although none of the experiments you will be doing in this course will likely be considered ground-breaking, it is good practice to follow these rules so that you will be prepared to keep an effective lab notebook when you finally graduate into the "real world".

- The lab notebook you purchase *must* have permanently bound pages, and must have graph paper. The following lab notebook can be purchased at the bookstore, and satisfies this requirement:

  - Roaring Spring Laboratory Notebook (77591).

  *It is your responsibility, if you choose to purchase a different lab notebook from the one listed above, to make sure it has permanently bound pages and graph paper.* Unfortunately, many of the other lab notebooks you might find at the bookstore are unacceptable, usually because the pages are perforated, and therefore removable. A lab notebook with removable pages cannot serve as a legal document.

- All writing in lab notebooks must be done in *permanent ink*. Blue or black ink is considered standard — all other colors should be avoided (especially red). *Pencil is completely unacceptable* — no valid legal document has ever been written in pencil.

- The use of white-out or any other eraser is strictly prohibited. If you make a mistake, neatly cross out the error with a single line. This makes it clear that what you are

crossing out is erroneous, without making it illegible. This serves two purposes: (1) it allows you to recover the data later if you should happen to discover that the "erroneous data" was in fact correct, and (2) it avoids giving the reader the impression that you may be trying to cover up something. A lab notebook which is full of erasures, white-out, and illegible cross-outs will naturally be regarded with suspicion.

- All data and observations must be written down directly into the lab notebook. Taking original data on "scratch paper" and then transferring the data into the lab notebook is error-prone and involves a lot of unnecessary extra work. It can also lead to fraud, since it would then be possible to take the data, analyze it, decide if you like the outcome of the experiment, and only if you actually like the results will you then record the experiment in your lab notebook. *This practice is not considered good science.* Taking original data directly in the lab notebook avoids this problem.

- All pages must be numbered consecutively, starting with 1. If the lab notebook you purchase does not already have page numbers, you must number the pages yourself. It takes about 20 minutes to number a 120-page lab notebook, so be sure to do this before coming to the first lab. Page numbering will be graded after the first lab.

  Proper sequential page numbering and permanently bound pages can both serve as evidence that the lab notebook has not been tampered with — all pages that were ever part of the lab notebook are clearly still there.

  Page numbers are also useful for cross-referencing.

- All pages should also be dated when they are used. This will also be checked after each lab. Establishing the date when measurements occurred can be crucial when applying for a patent, or otherwise establishing precedence over another research group.

- The first page in the lab notebook should be reserved for the Table of Contents. It may be a good idea to write the words "Table of Contents" across the top of the first page when you purchase the notebook, so you don't make the critical mistake of using the first page to take data when you perform the first lab. The Table of Contents will be filled in as you do each lab — indicate the name of the lab, the date it was performed, and the starting and ending page numbers. Be sure to leave room in the Table of Contents for each lab's grade.[1]

- You must not leave any significant amount of blank space in your lab notebook. Blank space implies that you intend to fill the space in with data you will be taking later, which constitutes fraud. *This is very important.*

[1]The rules regarding dating each page and not leaving significant blank space obviously do not apply to the Table of Contents page. However, this page should still be numbered.

If you find yourself with some blank space left over at the bottom of a page, draw a line separating the blank area from the written areas and cross-hatch the blank area. This demonstrates your intention *not* to use the space later.

- Any notes you may have written on a separate page (e.g., any notes you took while at home before the lab) that you want to include in your lab notebook must abide by the rules stated above and be neatly taped into the lab notebook (technically, these items should be *glued* into the notebook, but we have to be practical). In particular, the inserted pages should be neatly written in ink with no erasures, white-out, or illegible cross-outs, contain no significant blank space, and should be dated (use the date you wrote the notes, not the date you inserted it into the lab notebook).

- It is understood that certain parts of the lab may be out of sequence in your lab notebook. This is okay, so long as what is written in your lab notebook actually reflects the order in which you performed the lab.

Many of the requirements listed above are necessary for a lab notebook to be considered a legal document. In order to serve this purpose, it must be clear to the reader that the lab notebook includes all data, observations, analysis, and conclusions made by the researcher on the dates indicated in the lab notebook, and that nothing has been removed or added later. Removable pages, non-sequentially numbered pages, undated pages, frequent erasures, the use of pencil, and/or frequent large areas of blank space all cast doubt on the authenticity of the lab notebook.

## Copying versus cheating

One of the most important requirements in this, or *any* course for that matter, *is that each student must turn in his or her own work*. Of course it is also important to realize that the individual members of a lab group are working together and are taking the same data. So what are you allowed to share with your lab partners, and what constitutes cheating?

The rules are very simple: the only thing you are permitted to copy from your lab partner's notebook to your own notebook is raw data taken during the experiment, and only if you participated in taking that data. In other words, it is perfectly acceptable for one student to copy down the raw data as the other students perform the measurement, and then the other students copy the data from the first student (in such cases, students should switch roles during the experiment so that every student has an opportunity to work with the equipment). However, you may *not* copy any data analysis, results, conclusions, answers to questions, or other comments from another student's lab notebook. Of course, you are permitted to *discuss* these other aspects of the lab with your lab partners, or with other students. However, *what you write in your lab notebook must be in your own words*.

You are also *not* permitted to copy raw data from another student's lab notebook if you were not present when that data was taken (e.g., if you came late, after the measurement

was taken). In such cases, you must repeat the measurement yourself. I will be taking attendance during the lab, so I will know who is actually present during the lab.

## What to write in the lab notebook

Naturally, everyone's lab notebook style is going to be different. Nevertheless, there are some general guidelines about what you should write in the lab notebook.

First of all, all good writers have an idea of who their target audience is. You should assume that the person reading your lab notebook has already taken PHYC 4B (lecture), and therefore has basic knowledge of the theory (e.g., the reader already knows what "voltage", "current", and "resistance" mean), but has never taken the lab course. You may assume that your reader has read the lab write-up (so you don't have to rewrite significant portions of the lab write-up in your lab notebook), but has not performed the lab. Your goal as a writer is to explain all the details of what happened during the lab and *why* you think you got the results that you did. The lab notebook should be clear, concise, and complete enough so that the reader can understand what took place without having to step foot in the lab, and could also, if s/he chooses, perform the lab him/herself and *verify* what you have done. *All good scientific results are reproducible, and a well-written lab notebook should allow others to confirm your results.*

Each lab should begin with a new page, and start with the lab's title at the top of the page, the date the lab was performed, and the lab partners who were present that day to help you.

You should then state the *goals* of the lab, which is a one or two sentence description of what you expect to accomplish during the lab. You do not need to be overly detailed about the procedure of the lab, since that is written up in the lab write-up. *Be sure to read the lab write-up before coming to the lab.* If you do, and you have thought about what you have read, you will already have some idea what the goals of the lab are before you arrive.

If you brought some notes from home, this would be a good place to insert them into your lab notebook. If you did not, you might want to take some time to write down any preliminary thoughts you have about the lab.

You should also list the equipment you expect to use in the lab. It is a good idea to identify the equipment you are using, by number if possible (the circuit board kits and oscilloscopes are numbered — I believe some of the power supplies and meters may also be numbered as well). That way, if you later suspect that there may be a fault in the equipment, you can go back and check.

You should also draw a diagram of any setup you will be using during the lab. For example, if you build a circuit during the course of the lab, you should include the circuit diagram in your lab notebook and refer to it when taking data.

You should now be in a position to start performing the activities of the lab. All data should be recorded in your lab notebook. When you take a measurement, be sure to include

units with the number. Also, if you are reading a digital display, *all* digits displayed should be recorded, including trailing zeros (e.g., if the voltmeter display shows "1.00", record the voltage as 1.00 V, not 1 V). When reading an analog meter, include at least two, if not three, significant figures, and *be consistent*.

You should also, when appropriate, indicate *which* instrument you used to take the measurement and what the settings of the instrument were. As an example, we will be using two different multimeters in this course: you should indicate which one you used to take a particular measurement, and what the range setting was. You will need this information if you want to calculate uncertainties, and your reader will also need this information if s/he is trying to reproduce your results.

You should also note any unusual observations that you make during the experiment, as these observations may turn out to be important later. For example, if the last digit on the digital multimeter is fluctuating, indicate this fact in your lab notebook. If it took two minutes for the instrument reading to reach its final value, write this fact down.[2] And so on.

If you find that you have made a mistake when taking a measurement, you may cross out the erroneous data. Remember to cross it out with a *single line*, so that it is still legible. You should also take the time to explain why you believe the data to be erroneous, even if the mistake seems silly to you (don't be embarrassed: we *all* make silly mistakes from time to time). This may help you or someone else avoid making that same mistake later. On a more practical note: it may help you avoid making that same mistake on the exam. *Indicating potential pitfalls and trouble spots when performing the lab is definitely encouraged.*

Data tables should be arranged vertically, with clear headings indicating what is measured. Units should be indicated in the table headings.

Unless stated otherwise, all graphs should be hand-drawn directly into your lab notebook. You should use the graph paper in your lab notebook (remember, one of the requirements is that your lab notebook must have graph paper). All graphs should have titles which clearly explain what the graph is for. Axes should be clearly marked and labeled *with units*. You should choose an appropriate scale for your graph (tick marks every 1, 2, 5, or 10 blocks which are labeled with values based on 1, 2, 5, or 10). Graphs should take up most or all of the page. *Analyzing larger graphs gives better results, period.*

The raw data used to plot points on the graph should be written down somewhere in your lab notebook. You should cross-reference the data table and the graph with page numbers (the graph should refer to the data table, and the data table should refer to the graph). It is the height of cruelty to expect the reader to be able to find the data table on which your graph is based (especially if that table is 10 pages away) without telling him/her what page it is on. Remember, that reader could be you several years from now, or during an exam.

You will have occasion during this lab course to plot graphs from an oscilloscope display. In this case, you should indicate the oscilloscope settings used to generate the display. You

[2] This actually happened to me when I was doing one of the labs in this course. That observation turned out to be important.

should also label the vertical and horizontal axes with appropriate units (time or voltage units for the horizontal axis, and voltage units for the vertical axis).

Calculations should be written out as fully as is reasonable. Remember that your reader (which may be you during an exam) may not know or remember how to perform the calculation. Naturally, calculations which are repeated several times during the lab may be written out in detail just once.

When calculating the slope of a straight-line fit to a graph, be sure to indicate the graph whose slope you are calculating. You should also clearly indicate which two points on the straight line you are using to calculate the slope — indicate this both on the graph and in the calculation. *Always use two points on the straight line itself — never use data points to calculate the slope.*[3]

Final results (with uncertainties, whenever possible) should be clearly marked as such, and *explained*. Comparisons to theory should be made (e.g., if two values are supposed to be equal, and you have calculated uncertainties for both values, you should compare them with the discrepancy test), and if any discrepancies are found, you should try to explain what may have gone wrong. *If it is at all practical, you should try to test your hypothesis with further experimentation to see if your explanation actually makes sense.*

If various final results are spread throughout the lab notebook, you may want to summarize the results by putting them in a table.

When you have completed the lab, the last thing you should write in the lab notebook is the conclusion, which should be an overall summary of the lab. A good format for the conclusion is to first summarize (without going into much detail) what you did in the lab, and then summarize the results you got, along with explanations of those results. You should keep in mind that your reader may read this section *first* in order to get an overview of the lab. Make sure your conclusion helps the reader in this case.

After finishing the lab, you should check the lab notebook to make sure that you

- have completed all parts of the lab and answered all of the questions.
- dated every page you used for that lab.
- cross-hatched out any significant blank space left at the bottom of any pages.
- placed an entry for the lab in the Table of Contents.

And of course, don't forget to clean up the lab station and put everything away.

[3]There is a rare exception to this principle which will come up in one of the labs.